WPS5621

Policy Research Working Paper 5621

Agriculture and the Clean Development Mechanism

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April 2011

Abstract

Many experts believe that low-cost mitigation opportunities in agriculture are abundant and comparable in scale to those found in the energy sector. They are mostly located in developing countries and have to do with how land is used. By investing in projects under the Clean Development Mechanism (CDM), countries can tap these opportunities to meet their own Kyoto Protocol obligations. The CDM has been successful in financing some types of agricultural projects, including projects that capture methane or use agricultural by-products as an energy source. But agricultural land-use projects are scarce under the CDM. This represents a missed opportunity to promote sustainable rural development since land-use projects that sequester carbon in soils can help reverse declining soil fertility, a root cause of stagnant agricultural productivity. This paper reviews the process leading to current CDM implementation rules and describes how the rules, in combination with challenging features of land-use projects, raise transaction costs and lower demand for land-use credits. Procedures by which developed countries assess their own mitigation performance are discussed as a way of redressing current constraints on CDM investments. Nevertheless, even with improvements to the CDM, an under-investment in agricultural land-use projects is likely, since there are hurdles to capturing associated ancillary benefits privately. Alternative approaches outside the CDM are discussed, including those that build on recent decisions taken by governments in Copenhagen and Cancun.

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Keywords: Agriculture, Clean Development Mechanism, climate change, land use, mitigation, soil carbon sequestration

JEL classification: Q15, Q54, Q56, O13

The authors would like to thank Philippe Ambrosi, Ellysar Baroudy, Marjory-Anne Bromhead and two anonymous reviewers for helpful comments on earlier drafts.

Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), agriculture accounted for an estimated 5.1 to 6.1 $GtCO_2e$ in 2005, or roughly 12 percent of global anthropogenic emissions of greenhouse gases. At the same time there is a consensus that agriculture's net contribution to global warming could be greatly reduced, since the sector also provides ample mitigation opportunities – enough to remove or sequester up to 1.6 $GtCO_2e$ annually at relatively low carbon prices. Most opportunities identified to date involve the use of agricultural biomass to generate power or involve changes in how agricultural lands are used (Smith et al., 2007). Especially important for mitigation are efforts to restore carbon pools in soil on degraded land. This closely links mitigation in agriculture with development, since most agricultural land-use opportunities are in developing countries where agriculture is an important source of income for the poor. Moreover, projects that sequester carbon in soils also help to reverse declining soil fertility, a root cause of stagnant agricultural productivity in Africa.

Under the Kyoto Protocol, countries that have pledged to reduce their emissions of greenhouse gases can invest in mitigation projects located in developing countries as a way of fulfilling their treaty obligations. The framework for this type of project investment is the Clean Development Mechanism (CDM). In this paper we examine the types of agricultural projects currently financed under the CDM. We find that most projects have to do with agriculture as a source of bio-energy, and that few projects tap the mitigation potential associated with changing how agricultural lands are used. We explore why this is so. We look at the aspects of agricultural land-use projects that make them complex and costly to implement under current CDM rules. We also examine the origins of the current CDM institutions and look at the feasibility of changing CDM rules to provide greater scope for agricultural projects. We review a set of new instruments arising from decisions taken by parties to the UNFCCC in Copenhagen and Cancun and explore new mechanisms outside of the CDM that could be used to integrate mitigation, development and sustainable resource management goals.

Potential sources of mitigation in agriculture

In 2007 the IPCC reviewed projections across a range of modeling efforts to assess potential sources of mitigation by sector (Barker et al., 2007). Table 1 summarizes the report's assessment of mitigation opportunities at US$20 per tCO_2e.[1] Recalling that the CDM is meant to target low cost abatement opportunities in developing countries, the assessment suggests that the opportunities are greatest in the building, industry and agricultural sectors. Moreover, the report concludes that most energy-saving efforts in the building sector would be profitable without additional carbon payments and are therefore ineligible for

[1] The Kyoto Protocol covers six gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). By convention, aggregate emission and mitigation amounts are expressed in terms of CO_2e, the amount of CO_2 needed to have the same global warming potential.

CDM crediting.[2] Consequently, modeling results imply that agricultural projects should feature prominently in the CDM.

As the more detailed chapter of the IPCC on agriculture makes clear, the consensus estimate of 1.6 $GtCO_2e$ in mitigation potential is based on models in which the sector is narrowly defined, focusing on on-farm activities primarily involving crops and livestock and the handling of animal wastes (Smith et al., 2007). The authors note that, as a consequence, additional opportunities linked to the use of organic agricultural waste products, such as baggasse or rice husks, as a renewable fuel are not counted toward agriculture, but are attributed to sectors in which the fuel-switching takes place. Top-down studies referenced in the report suggest that this class of opportunities for mitigation is nearly as large as agriculture's on-farm potential, with mitigation estimates ranging from 0.7 to 1.26 $gtCO_2e$ per year by 2030 at costs of US$20 or below.

As Smith et al. (2008) emphasize, measuring the mitigation potential for agricultural land-use is complex because a single activity can initiate a chain of emission outcomes among a portfolio of greenhouse gasses that also depend on local soils and local climate conditions. As an example, the authors cite evidence presented in Paustian et al. (2004) showing that composting manure can suppress methane emissions while simultaneously accelerating emissions of another greenhouse gas, nitrous oxide. Similarly, soil restoration can encourage carbon uptake in plants and soils, while stimulating the release of carbon through the decomposition of organic matter.

After accounting for interrelated effects, the authors provide a further breakdown of the mitigation potential for a set of agricultural activities under a range of carbon prices, shown in Figure 1. Keeping in mind that mitigation activities linked to agricultural biomass are excluded, the reported literature suggests that most mitigation opportunities are related to soil and land management practices that generate net sequestration gains. At low carbon prices (less than US$20), cropland management practices are key sources of mitigation, along with other land management practices, including the restoration of organic soils, degraded lands and improved management of grazing.

In the case of cropland management, improved agronomy is important, for example, converting crop production from traditional to improved higher-yielding varieties. So is the use of chemical fertilizers, which can provide net emission benefits when soils are poor. This is true even though carbon is released in the production and transport of chemical fertilizers and nitrous oxide is generated when nitrogen fertilizers are used. Other productivity-enhancing activities identified in the report include the use of ground cover between perennial tree crops and the adoption of crop-rotation schemes involving nitrogen-fixing legumes. Better water management and the application of organic matter to cropland are also identified as activities that both

[2] In the CDM parlance, these projects lack "economic additionality", that is, under a business-as-usual scenario, firms would find investing in this type of energy saving profitable and do not face hurdles that would prevent them from doing so.

enhance agricultural productivity and contribute to the restoration of organic soils on degraded lands. Important but smaller mitigation opportunities are tied to efforts designed to reduce methane emissions from wetland rice, livestock and manure.

Agricultural and land-use projects under the CDM

We next turn our attention to the set of agricultural projects approved or waiting approval by the CDM Board. The purpose is both to describe the flow of investments to agriculture under the CDM and to gauge the degree to which the mechanism has been able to tap potential mitigation opportunities identified in the IPCC report. The first step in that process is settling on a definition, since the classification systems used by the IPCC in their mitigation reports and by the United Nations Environment Programme Risoe Center on Energy, Climate and Sustainable Development (Risoe) to report on CDM projects are not harmonized. Indeed, Risoe classifies only two projects as agricultural.[3] Projects related to land use, the primary focus of the IPCC chapter on agriculture, are included under afforestation/reforestation projects, which we refer to as land-use-forestry projects.[4] Other projects related to agriculture – for example systems to manage manure or projects that use agricultural waste products to generate energy -- fall into other aggregate categories in the Risoe classification system, such as biomass energy or methane avoidance, which include non-agricultural projects as well. Consequently, for our purposes, we follow the lead of the United Nations' Food and Agriculture Organization (FAO) and define an agricultural project as a project that uses agricultural residuals, outputs or agricultural processes to directly or indirectly reduce greenhouse gas emissions (FAO, 2010). This definition is broad enough to include projects that sequester carbon in soils. Like the IPCC, we do not classify biofuel projects as agricultural, but we do include projects in which residual agricultural organic matter is used to produce energy. We include projects that reduce methane emissions from composting agricultural waste products, but do not include waste water projects, even though some waste water is likely associated with processing agricultural products.

There are multiple stages in the CDM project cycle and projects can leave the project cycle at several points. For the purpose of this paper, we focus on 5,824 projects that were active as of December 1, 2010. The number of projects and their projected cumulative and average mitigation impacts by project type are given in Table 2. By our definition, about 17 percent of the projects are classified as agricultural and land-use forestry projects, a category that includes mixed-use agro-forestry projects and other projects that restore agricultural land, comprise another one percent. In combination this is a significant share when compared to other categories, and only the hydro-power and alternative energy categories contain more projects. Based on Risoe's analysis of project documents, the identified agricultural projects are expected to reduce business-as-

[3] Both projects, only one of which remained active in 2010, reduced pump-well emissions by installing more efficiency drip irrigation systems.
[4] In UNFCCC parlance, the class of mitigation projects that sequester carbon in soils and forests are known as land use, land use change and forestry (LULUCF) projects, since the net mitigation comes from changing how land is used.

usual emissions by nearly 220 mtCO2e by 2012 and 582 mtCO2e by 2020. In addition, land-use-forestry projects are expected to account for another 17 mtCO2e and 69 mtCO2e respectively for the two periods. Even so, as the last two columns of the table indicate, agriculture projects and to a lesser degree land-use projects tend to be smaller scaled than other types of projects, so the share of the mitigation impact shares are smaller than the project count shares.

The task of comparing the potential for mitigation identified by the IPCC and the expected level of mitigation from projects in the CDM pipeline requires a series of assumptions and extrapolation. For one, the modeling efforts behind the IPCC estimates envisage annual flows by 2030 under a set of certain prices and established markets. In contrast, the CDM market has been built from scratch and investments have been made under uncertainty. Moreover, project offset prices have stayed below US$20 per ton since 2008, hovering mostly between $10 and $13 per ton. It is also worth pointing out that the CDM was never expected to finance the full set of mitigation opportunities in developing countries and that the CDM is in fact on tract to exceed expectations (Rahman, Dinar and Larson, 2010.) Still, the comparisons, though inexact, are indicative since they give a sense of how effectively the CDM has tapped opportunities across sectors.

With this in mind, converting the total cumulative stock of offsets expected from the pipeline for the period 2008 to 2020 works out to an annual flow of about 675 mtCO2e. Since the start of the CDM, the pace of projects entering the pipeline has increased and there are good reasons to expect this to continue if uncertainty over crediting after 2012 can be resolved. Still, the projected impact of pipeline projects represents less than ten percent of the potential 2030 flow of 6,900 mtCO2e of low-cost mitigation opportunities in developing countries identified by the IPCC.

Drawing a similar comparison about the gap between mitigation potential and the expected output from implemented projects is more difficult for agriculture. Part of this is conceptual and has to do with the already discussed differences between the modeling evaluations of what types of mitigation processes are agricultural and the classification system we use to categorize projects under the CDM. However, setting this aside, there is a practical problem in that the agricultural bio-energy estimates from the IPCC report do not identify the potential from developing countries separately. In general, the IPCC estimates that roughly 42 percent of the mitigation opportunities in energy are in developing countries and, by that rubric, about 302.4 mtCO2e of the agriculture-biomass potential should be in developing countries. Combining this with the potential from agriculture gives an estimate of about 1,629 mtCO2e. Generously combining the mitigation estimates for all 1,022 projects associated with land-use and agriculture provides a flow of just over 50 mtCO2e, a bit more than three percent of the IPCC total. Because we've included all reforestation and afforestation projects in the CDM total (regardless of whether they relate to the restoration of agricultural land), and because we have been generous in estimating the share of agricultural biomass potential attributed to developing countries, this already small share is most likely inflated.

A well documented, if not anticipated, feature of the CDM is that a large portion of the projects are located in a handful of countries. The same holds true of agricultural projects. As shown in Table 3, China, India, Brazil, Mexico and Malaysia account for 78 percent of all the CDM projects in our analysis, regardless of project type. Although there are minor differences in the ranking, the same five countries account for about 79 percent of agriculture projects. Relatively few projects are located in Africa. However, this is not the case for forestry projects. Even though this category accounts for few projects, the projects are more broadly distributed across hosting countries with a significant share of the projects in Africa.

Baseline methodologies for agricultural and land-use forestry projects

Because the developing countries that host CDM projects do not limit overall emissions, project mitigation affects are measured against a business-as-usual counterfactual. In UNFCCC parlance, the way of assessing the net mitigation consequences of a particular project is known as a CDM methodology. The methodologies are detailed and specific to particular processes. For example, specific methodologies lay out procedures for measuring the impact of updating municipal heating systems or incinerating hydrofluorocarbons. New projects can use methodologies that have already been approved when appropriate; however projects that introduce new methods or modify existing ones must have those methods approved by an expert committee before the project will be considered by the CDM Board.

The methodologies used for the 1,022 projects studied here are listed in Table 4.[5] The projects rely on 33 approved methodologies, but the ten most frequently used methodologies account for 80 percent of the projects. Often, more than one methodology is used in a given project. For example, a project might move organic material that would normally be left to decompose in a contained area, capture methane released during decomposition, and use it to generate electricity. When requesting credit from the CDM Board, project sponsors may use one methodology to account for the conversion of methane to less harmful carbon dioxide as the methane is burned, and another to calculate the benefits of displacing electricity produced with fossil fuels with electricity from a renewable resource.[6]

The fixed costs of bringing a project to the CDM Board and the on-going monitoring costs can be high, so to encourage small scale projects, the CDM Board distinguishes between small scale and large scale project methodologies. As can be seen in the table, agricultural and forestry projects contain a mix of small and large scale projects. Because of this, the methodologies that are most used are not strictly the same as those methodologies associated with high levels of expected mitigation.

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[5] As the set of methodologies grows, similar methodologies are harmonized in a "consolidated" methodology. In our classification, we use the most recent methodology designation; that is, we group each consolidated method with their respective antecedents.

[6] Consequently, the sum of methods used exceeds the number of projects.

Once approved, methodologies enter the public domain and can be used by subsequent project developers. For this reason, methodologies tend to follow a life cycle in which the use of the methodology increases as developers look for low-cost opportunities to replicate the methodology and then declines as replicable opportunities are more fully exploited (Table 5).

The methodologies exactly define the specific activities allowed under the CDM. Table 4 suggests that there are 33 actions associated with agriculture and forestry. However, a close look at the most widely used methodologies, suggests that the methods are variations around a smaller set of core actions.

AMS-I.D is methodology used to calculate the mitigation effects of displacing fossil fuels to generate electricity that enters a power grid from small-scale projects. ACM6 is a related consolidated methodology for larger scale projects in which fossil fuels used to generate electricity and heat under the business-as-usual baseline are replaced by biomass residuals – for example, risk husks or the residual from crushed sugar cane. The methodology takes into account methane avoided by burning the residue rather than allowing it to decay. AMS-III.D is a methodology to account for recovering and burning methane in small-scale animal manure management systems. AMS.I.C is also a methodology based on burning biomass; however, it also can be applied to small projects that improve the efficiency of existing biomass projects – for example, the installation of equipment that improves the efficiency of thermal power components of a sugarcane crushing facility. AMS-III.F is another small-scale methodology based on the avoidance of methane emissions. In this case, methane emissions are avoided by composting organic material normally left in the open to decay, or by capturing biogas that is flared and potentially used to produce electricity. The methodology is often implemented at palm oil processing plants. ACM2 is a large scale consolidated baseline methodology for grid-connected electricity generation from renewable sources. In the case of the projects studied here, it is most often used in connection with ACM6. AMS-III.E is another methodology based on the avoidance of methane produced from decay, mostly through controlled burning or through gasification. ACM3 is a large-scale consolidated methodology based on the use of alternative fuels in the production of cement. In a few cases, the alternative fuel is based on agricultural residues, which is how the methodology came to be included in our study. Allowing for some double counting of projects that use multiple methods, these eight methodologies account for roughly 86 percent of the projects and about 78 percent of expected mitigation impact from the projects that we include in our study.

Among the remaining methodologies, five are significant for agricultural land use. The most used land-use methodology in our sample is AR-AMS1, a simplified baseline and monitoring methodology for planting trees on grasslands or cropland while maintaining most pre-project activities. This is significant, since some land-use methodologies prohibit continued grazing on lands covered by the project. AR-ACM2 is a related large scale methodology, where pre-existing farming activities are continued after project implementation. AR-AM4 is a methodology based on planting trees and shrubs on degraded land that is used for agricultural purposes. AR-AM5 is a related methodology for commercial agricultural purposes. Land-use methodologies account for about 4 percent of the study sample and about 8 percent of expected mitigation.

Table 6 uses information from the methodologies to reclassify projects by a core set of activities. From the table, it is clear that more than 80 percent of the projects and expected mitigation impact is associated with either using left-over agricultural matter (primarily rice husks, baggasse and oil palm husks), or the management of manure in a way that captures methane and converts it to less harmful carbon dioxide and frequently energy as well. Afforestation, reforestation and composting projects account for most of the remaining projects. The remaining two projects are based on energy efficiency gains.[7]

Project markets outside the CDM

Not all projects designed to mitigate greenhouse gas emissions from agriculture operate under the UN Framework. Voluntary markets offer an alternative way of financing agricultural land-use projects. Overall, these markets are small relative to regulated markets, including the CDM (Table 7). However, they are significant and collectively finance a greater volume of offsets than Joint Implementation.[8] Most voluntary market transactions originate in the United States, which is not a party to the Kyoto Protocol.[9] Projects traded in voluntary markets are not subject to the same types of review and public disclosure that characterize the CDM market; however the application of third-party standards is common. In their annual review of voluntary markets, Hamilton et al. (2010) estimated that over 90 percent of voluntary transactions in 2008 and 2009 adhered to third-party standards, but also counted 18 competing standards active in voluntary markets.

In some cases, the types of projects financed by voluntary markets are similar to classes of projects eligible for financing under the CDM. For example, in 2009 landfill and wind projects accounted for 39 percent of the offsets financed by voluntary markets (Hamilton et al., 2010). Still, investors have been attracted to the voluntary market as a way to invest in land-use projects that are difficult to finance or have been excluded from financing under the CDM.

An estimate of land-based credits financed through voluntary markets is reported in Table 8. Though the combined volumes of land-based projects in 2008 and 2009 were small, the projects collectively represented a significant share of the voluntary market. Nevertheless, among these, the portion of credits arising from agricultural land-use projects remained quite small, constituting four percent of the voluntary market in 2009 and less than one percent in 2008.

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[7] The irrigation project, set in India, saves fuel by using more intensive farming methods; the mangrove project, set in Cameroon, improves the efficiency of wood-burning stoves used in smokehouses, thereby reducing wood consumption.
[8] Joint Implementation is a second project-based mechanisms established by the Kyoto Protocol for projects based in countries that have pledged reductions.
[9] Hamilton et al. (2010) estimates that 56 percent of voluntary project transactions took place in the United States.

Hurdles to including agricultural projects in the CDM

In the previous section we described the gap between the available mitigation opportunities in agricultural land-use projects and capital flows from the CDM and from voluntary markets. In this section, we examine specific design features of the CDM that work against land-use projects in general and discuss the origins of these features. We then explore how the practical concerns that gave rise to this structure also work to limit funding from markets outside of the Kyoto mechanisms.

Purposely, the CDM is designed to facilitate capital flows to developing countries to tap low-cost mitigation opportunities and to promote sustainable development in countries that have not themselves pledged emission reductions. But this basic design tenet of the mechanism has vocal critics and support for the mechanism, even among some signatories of the Kyoto Protocol, has been equivocal. One consequence is a set of varied national policies and a complex set of international implementation rules that try to remediate concerns about the environmental efficacy of the CDM and its impact on development. Additionally and separate from the underlying questions that motivated their genesis, the mechanism's implementation rules give the CDM a particular institutional structure that has practical consequences, influencing the type of mitigation efforts feasible in developing countries within the UNFCCC. For the most part, this structure works against the development of projects related to how land is used and this, in turn, works to preclude the types of projects that would target the largest sources of low-cost mitigation opportunities within agricultural sectors. More generally, it also explains why the country and sector composition of the projects that now constitute the CDM project cycle pipeline differ from estimates of the sector-distribution of low-cost mitigation opportunities discussed earlier.

Objections to the CDM and their influence on its design

The Clean Development Mechanism, dubbed the "Kyoto surprise," emerged late in the negotiations of the Kyoto Protocol and has been called the least loved of Kyoto's contentious flexibility mechanisms (Werksman, 1998). The mechanism was intended to address two divergent set of interests: a desire by developed countries to access low-cost mitigation opportunities in developing countries; and a need by developing countries for a new channel for development assistance (Grubb et al. 1999; Lecoq and Ambrosi 2007). Moreover, for the mechanism to work, the difficult problem of finding a way to create environmentally sound credits in countries without pledged limits had to be solved.

Although the CDM was outlined in broad strokes in the 1997 Kyoto Protocol, the practical design of the mechanism was worked out in a protracted set of negotiations, which were not fully concluded until 2003. The rules that emerged partly reflected the early divergent views that had made negotiation over the mechanism so difficult. But they also reflected the difficult and technical challenges of designing and verifying project-based mitigation efforts when only one of the parties faces emission limits. [10]

Lecocq and Ambrosi (2007) identify four key areas of conflict that still shape the CDM: i) tensions over the use of flexibility mechanisms in general; ii) disagreement over the procedures for creating new credits under the CDM; iii) tension over how to accommodate the twin objectives of mitigation and development under the CDM; and iv) controversy over the consequences and permanency of forestry and other land-use projects[11].

Flexibility mechanisms

In the lead-up to the Kyoto Protocol, flexibility mechanisms were strongly opposed by several NGOs and some European negotiators, largely on normative grounds. For these groups, developed countries that contributed most to the accumulative of greenhouse gases over time were morally bound to redress the problem by acting within their own borders. Other groups went further, arguing that CDM would be exploitive and erode the authority of developing country governments. [12]

In some cases, opposition to the flexibility mechanism may have been tactical. Negotiators had reached agreement on emission allocations before discussions on the flexibility mechanisms were complete. Consequently, groups already concerned that the aggregate supply of allowances had been set too high, may have chosen to focus on limiting how allowances could be used or new allowances created rather than revisiting the allocation decision.

The value of using CDM offsets and other tradable permits to reduce the cost of mitigation was questioned on positive grounds as well, as some modeling work suggested that low carbon prices would reduce incentives for new innovative technologies and result in long-run welfare losses.[13] The basic logic of the argument is that investments made when carbon prices are high are more likely to be associated with innovative technologies that generate positive externalities that, in turn, improve the productivity of other

[10] The mechanics of project-based mitigation had been explored prior to Kyoto in a series of national pilot programs known collectively as Activities Implemented Jointly, with mixed results. See Larson and Breustedt (2007) and references therein.

[11] Briefly, the Kyoto Protocol, an international agreement linked to the United Nations Framework Convention on Climate Change, allows the developed and transition countries that have pledged to limit their greenhouse gas emissions (Annex B countries) during the first commitment period (2008-12)) to meet their targets through domestic measures, or by acquiring three types of tradable offsets, that represent reductions taken abroad. One type of tradable "Kyoto units", Assigned Amount Units, is created when an Annex B country aggregate emissions fall below pledged levels. The other two types, Emission Reduction Units and Certified Emission Reduction credits (CERs) credits are project based, and stem from investments in Annex-B and non-Annex B countries (countries that have signed the Kyoto Protocol but have not pledged emission limits), respectively.

[12] Harvey and Bush (1997) provide an early discussion of normative issues.

[13] Conceptual and numerical models suggest that this construct holds under special circumstances. Arguments related to the long-term benefits, via induced innovation, of restricting emission trading are discussed in Matschoss and Welsch (2006) and Weber and Neuhoff (2010).See Larson et. al (2008) for a review.

firms. Said differently, advocates maintained that innovation increases as the shadow-price of capital devoted to mitigation increases – at least for a relevant set of carbon prices—and, over time, the benefits of improving the productivity of the mitigation function exceed the initially high costs of abatement.

In Kyoto, negotiators divided into separate camps and a coalition led by the EU and Swiss delegations pushed to place quantitative limits on the use of tradable credits. Language emerged in the final draft of the Protocol stating that the flexibility mechanisms would be "supplemental" to domestic actions, but, with the exception of forestry credits, quantitative restrictions were never imposed in subsequent rounds of rule making (Platjouw, 2009).[14] Nevertheless, national governments have leeway in how the flexibility mechanisms can be used within their borders, and several countries have imposed quantitative restrictions.

In the case of the European Emission Trading Scheme (EU-ETS), the aggregate use of Kyoto units is limited to 13.36 percent of the 2008-12 emission allocations; national rules vary. For example, Estonia forbids the use of Kyoto units, while Lithuania, Norway and Spain place a cap at 20 percent (Larson et al., 2008).[15] Moreover, in additions to general restrictions on CDM offsets, CERs originating from land- use projects are completely excluded from the EU-ETS, which has additional implications for pricing and finance, a topic that we return to later.

Creating new credits

There was also great skepticism about project-based mitigation (Lecocq and Ambrosi, 2007). A core concern had to do with the idea of using a hypothetical business-as-usual counterfactual scenario to determine the number of credits earned by a particular project. Elements of the counterfactual cannot be observed and the full implications of the project are to a degree speculative, opening the evaluation process to strategic manipulation.

Conceptually, firms that face binding constraints under cap-and-trade or in the form of a carbon tax will undertake mitigation efforts to the degree that the costs are matched by the added revenue associated with additional emissions. Importantly, the firms make their own judgment about the efficacy of capital invested in mitigation. Outside of the cap, a different set of incentives are in place. Firms that fail to take mitigation efforts are not penalized, but can be induced to mitigate if it is profitable to do so. Indeed, this is the underlying essence of the CDM, since many low-cost mitigation opportunities are located in countries where greenhouse gas emissions are not regulated.

In this case, a judgment external to the firm must be made about how an investment affects emissions, and this leads to potential problems of information asymmetry. This is because firms both inside and outside of

[14] See in particular Articles 6, 12 and 17 of the Kyoto Protocol.
[15] Operating since 2005, the EU-ETS mandates an overall limit or cap on carbon emissions that originate from large industrial facilities and electric power generating plants and allows the trading of emission permits under the cap. The program affects firms in the EU's 27 member states, plus Iceland, Liechtenstein and. Norway.

the cap stand to benefit from an exaggerated evaluation of an investment's impact since they can share a larger number of credits. A related difficulty is that new investments often affect emissions and production costs jointly. In this case, the private benefits from the investment (for example, from energy efficiency gains) must be subtracted from the cost of the investment used in the mitigation calculations. This becomes especially complex for projects where host firms face restricted access to capital, since the cost of capital enters into the calculation of economic additionality.[16]

A final difficulty has to do with indirect "leakages," that is, when a portion of the mitigation gains from a project are lost via general equilibrium effects. This can occur when actions taken by firms in the aggregate influence the set of relevant input and output prices, inducing a change in the behavior of others. As a consequence, a set of unexaggerated mitigation claims can be over-valued in the aggregate when the business-as-usual baseline analysis is performed on a firm-by-firm basis. Burniaux and Martins (2000), Barker et al. (2007), and Larson et al. (2008) provide reviews of the literature.

Because of the incentives for firms to exaggerate their mitigation claims and the technical challenges of fully accounting for the secondary effects of project investments, negotiators decided that environmental additionality would be tested on a project-by-project basis, rather than at a program level as some negotiators had proposed. Moreover, the review would be undertaken under the guidance of an independent Executive Board. This resulted in the current rules whereby the creation of credits requires both an initial approval of the baseline (counter-factual) methodology and monitoring methodology by the Executive Board, and a final certification of ex-post evidence that the mitigation had occurred.

The development objective and bilateral approval

As negotiations proceeded, there were several calls for a mechanism that would provide developing countries with a stream of revenue that could be used to promote mitigation activities. Most notable was the 1997 "Brazilian proposal," which envisioned penalties for countries that exceeded their pledged emission targets to be paid into a clean development fund to support mitigation efforts in non-Annex I countries (Matsuo, 2003). As the negotiations progressed, the idea of a central fund managed under the UNFCCC gave way to the notion that individual projects would likely benefit developing countries by improving access to capital and by fostering technology transfer. Consequently, it was left to host countries to determine on a case-by-case basis whether an individual project contributed to the host country's development objectives.[17]

The decision resulted in a series of implementation protocols. For a project to go forward, project developers must obtain a letter of approval from the host country government stating that the proposed CDM project

[16] These questions have to do with economic additionality, the situation where the mitigation benefits exceed the private benefits of the investment. In so-called win-win projects, this is not the case.
[17] Though separate from the CDM, special funds such provisions of the Global Environment Facility and the Clean Technology Fund have been established to assist mitigation efforts in developing countries.

activity contributes to sustainable development. Project developers must seek approval from the investor country as well, although it is only the host country that makes a determination of the project's developmental impact. To make this practical, each country designates a responsible agency (known as the designated national authority) to formally certify the project's contribution.

Not all designated authorities are equally efficient, so country-specific differences in transaction costs emerge. Moreover, not all host countries were equally prompt in establishing a designated authority. Both factors have likely influenced the skewed geographic distribution of projects discussed earlier.

Although the potential for the CDM to promote technology transfers motivated the mechanism's late inclusion in the Kyoto Protocol, no formal mandate merged. Still, some project organizers claim to promote transfers in the documents they present to the Executive Board. Based on an examination of 854 early projects, Haites, Duan and Seres (2006) found that 81 percent of projects related to agriculture claim technology transfer. By way of comparison, only 41 percent of wind-energy projects and 15 percent of hydro projects in their sample claimed to have transferred technology.

Land management projects

Rule-making for sinks and land-use projects proved especially difficult. While most rules for the CDM were in place following conferences in Bonn and Marrakech in 2001, it was not until a final set of rule-making in 2003 that the full set of guidelines for Land Use, Land-Use Change and Forestry (LULUCF) projects emerged (Lecocq and Abrosi, 2007). The rules that did eventually emerge were cautious and restrictive, and placed strict limits on the creation of land-use credits, and special restrictions that distinguished land-use credits from the credits produced in other sectors.[18]

As discussed, land-use projects are technically complex since changes made to capture greenhouse gases can initially release carbon into the atmosphere. A full accounting of the type required for most CDM projects involves measuring the net change in carbon stocks for particular sites as well as any related increases in emissions off-site, taking into account above-on-and-below-ground biomass and soil organic carbon. The projects are also long-lived and subject to reversibility because of human activity such as logging or natural events such as forest fires or disease. Consequently, many negotiators held deep reservations about whether the projects would deliver sound and permanent environmental benefits. Added to this was a concern that CDM-market economics would favor projects based on fast-growing industrial plantations, crowding out projects that are community-based and that promote biodiversity (Hunt, 2008; Boyd, 2009).

[18] The fact that rules for LULUCF projects came late penalized this class of projects as well, since it left less time for the project to generate offsets by 2012, the close of the first commitment period.

In particular, current rules permit afforestation and reforestation projects but exclude projects designed to slow deforestation.[19] Moreover, rules limit the total amount of land-use CERs that can be used to meet Kyoto obligations during the first commitment period to 5 percent of their base-year emissions; Bernoux et al. (2002) estimate that this limits the market for CDM land-use credits to 11 MtCO_2e for the first commitment period.

To address reversibility, a new set of credits were created with a special set of rules. To start, net removals from the project are certified every five years. Project developers can choose between two types of CERs: Long-term CERs (lCERs), which expire at the end of the project's crediting periods, or temporary CERs (tCERs) that expire at the end of the next commitment period. (For example, tCERs issued during the first commitment period would expire at the end of the second commitment period.) If the project performs as planned, new tCERs are issued to replace expiring ones until the end of the project's crediting period. However, Annex B countries that use tCERs during the first commitment period have to replace them during the next commitment period with so-called permanent credits (for example AAUs or CERs from non-LULUCF projects). The same restriction does not apply to the use of lCERs; however if the accumulated stocks of stored carbon from a projects for which lCERs have been issued declines during the five-year certifications, Annex-B countries must replace a proportional share of the lCERs that they used. If a project fails to submit a certification report, all lCERs issued to the project must be replaced.

Consequences for pricing and profitability

Built to redress weaknesses related to business-as-usual counterfactuals, features of the CDM project cycle also influence a set of transaction costs that vary among types of projects. Because of this, the overall cost of operating a project under the CDM can be high even when abatement costs are themselves low. This is the case for agricultural land-use projects, where the design of the CDM, the complex biochemistry of soil carbon sequestration and the frequent need to coordinate the activities of many land-users combine to inflate transactions costs. Moreover, many transaction costs are fixed and this works against small-scale projects in general, and smallholder and community-based projects in particular (Michaelowa et al., 2003; Skutsch, 2005).

Drawing on Dudek and Wiener(1996) and Cacho, Marshall and Milne (2005), Cahco and Lipper (2007) provide a topology of transaction costs for soil sequestration projects based on five categories: i) search and negotiation; ii) board approval; iii) project management; iv) monitoring and v) enforcement and insurance. Using this framework, the authors draw on published project reports for smallholder reforestation and afforestation projects to calculate project transaction costs by category. They find disparate results with wide differences among projects across all categories. They report search and negotiation costs ranging from

[19] Reforestation is the restoration of depleted forests, while afforestation is the conversion of other lands to forestlands.

US$22,000 to $160,000; and approval costs from $12,000 to $120,000. Differences in monitoring costs were remarkable, ranging from $5,000 to $270,000.[20]

As discussed, the formal rules associated with implementing the CDM also work to limit demand. For example, limits on how CERs can be used under the EU ETS prevent full arbitrage between the markets and consequently CDM credits trade at a discount to their European counter-parts.[21] The restriction spills into formal markets for price discovery and risk management as well; for example, CERs originating from land-use projects are excluded from the European Climate Exchange. Rules that exclude projects from the CDM also shift some projects to voluntary markets where credits trade at a steep discount to credits traded under the European Union ETS (EU ETS) or the CDM. For example while all carbon prices fell dramatically in 2008 as global economic conditions worsened, spot prices for CDM offsets still remained above US$15 tCO_2e for most of 2009. By comparison, the World Bank (2010) estimates that the price for voluntary credits averaged less than US$5 per ton.

In addition, market sentiment disfavoring land-use projects appears to extend beyond the effects of the formal rules. Outside of the CDM, this is revealed in the voluntary markets where offsets from land-use projects sell at a discount to other types of mitigation projects. In their review, Hamilton et al. (2010) noted that all of the over-the-counter agricultural soil credits they tracked originated on the Chicago Climate Exchange and, in line with that market, traded for an average price of US$1.20 per ton; forest carbon offsets sold for just under US$3 per ton and afforestation and reforestation credits sold for just over US$4 per ton, on average.

Evidence of revealed preferences for particular types of projects can be found within formal CDM markets as well, even though all types of tradable Kyoto offset units are notionally equivalent for the purpose of meeting treaty obligations. For example, State and Trends of the Carbon Market (World Bank, 2010) reports that owners of the most desirable renewable energy projects often by pass exchange platforms where no distinction made among CERs by origin in order to retain premiums of roughly 5 Euros per CER. A similar price differentiation occurs via the private branding of CDM projects, as land-use projects are frequently ineligible for some well-known third-party certification programs, including Gold Standard certification (Gold Standard Foundation, 2010).

Taken together, the restrictions land-use projects face during the CDM cycle, the formal restrictions placed on their use by governments, their disfavor among buyers, and higher transaction costs all work against the economic viability of land-use projects.

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[20] The authors found that enforcement and insurance costs were largely unreported.
[21] For example, the EUA-CER price spread ranged between 2-3 Euros during the first 9 months of 2010. (Tendances Crbone, 2010)

Ancillary benefits and sustainable rural development

For many, the limited scope for agricultural land-use projects under the CDM represents a missed opportunity to finance sustainable development. This argument rests on two foundations. The first has to do with the sector composition of current investment flows, already discussed in an earlier section. The notion here is that while the benefits of slowing climate change are especially important to the rural poor, the current composition of projects favor the energy sectors and manufacturing and consequently have little impact on this generation of the rural poor.[22] The second set of arguments, explored in the next section, has to do with the fundamental role played by soil carbon for agriculture and soil fertility management.

Soil carbon sequestration and productivity

Especially in Africa, soil carbon sequestration is closely tied to agricultural productivity and consequently food security and reduced poverty. Vågen, Lal and Singh (2005) note that soils are degraded on more than 3.5 million km^2 of land in Sub-Saharan Africa and this accounts for roughly 20-25 percent of land area. Of this, estimates suggest that 1.1 million km^2 is severely degraded. To make matters worse, Henao and Baanate (2006), reported in Morris et al. (2007), estimate that 85 percent of African farmland suffers soil nutrient losses at a rate of 30 kg per year or greater.[23] Especially in remote places, high transport and transaction costs push up the farm-gate price of chemical fertilizers and this encourages farming practices that further degrade the land and discourages the adoption of higher yielding grain varieties.[24] Marshalling payments for the adoption of farming practices that reverse this downward cycle is seen as a strategic way of promoting sustainable agricultural practices (Antle and Diagana, 2003).

Numeric studies suggest that the ancillary productivity benefits of adopting carbon sequestering farming practices that come via higher yields are the dominant source of welfare gains for farmers working degraded soils. This comes about because of a confluence of factors, primarily the price of carbon credits, the price of agricultural output, the sequestration capacity of the soils and monitoring costs. Using indicative numbers, Graff-Zivin and Lipper (2008) estimated that carbon-market related returns associated with switching from traditional to carbon-sequestering conservation methods ranged from US$0.90 to $15 per hectare, amounts that are unlikely to motivate changes in farming practices. To emphasize their point, the authors reference a study set in Senegal (FAO, 2004) that estimated the returns from marketable soil carbon credits amounted to less than four percent of household income. In contrast, productivity benefits are often large. This is illustrated in Table 9. The table is constructed from a study by Tennigkeit et al. (2009) that looks at a stylized carbon sequestration problem for African maize on degraded soils under four farming practices. In all cases, the returns from improved yields exceed the gains from carbon credit sales.

[22] See, for example, Sirohi (2007) who looks at the composition of CDM investments in India.
[23] Smaling et al. (1993) report even higher levels in Western Kenya.
[24] See Zerfu and Larson (2010) and references therein.

Still, the juxtaposition of large ancillary benefits from adopting soil-sequestering farming methods and the widespread use of farming practices that degrade soils is part of a large puzzle of why farmers in developing countries fail to adopt more profitable and sustainable technologies (Larson and Plessmann, 2009). Hurdles to technology adoption include limited knowledge by farmers about the practices in combination with poor access to extension services. Limited access to credit can constrain technology adoption as well, since productive practices often require the up-front purchases of more costly seeds and fertilizers that poor farmers are unable to self-finance. Moreover, adopting new technologies can be risky since the higher up-front costs can magnify potential economic losses due to bad weather or poor output prices. Consequently, farmers may choose not to adopt improved technologies when formal and informal insurance markets are weak and they are unable to self-insure.

Many of the same hurdles apply to the decision to take up soil carbon sequestering technologies and often additional hurdles as well. Particularly in the case of conservation agriculture, changes in soil management practices lead to a change in the soil ecosystem; indeed, this is the underlying objective. However, during a transition stage in which the soil system move from one equilibrium to another, vulnerabilities associated with weeds or soil-borne pests or pathogens shift, leading to greater uncertainty about yields (Hobbs, 2007; Graff-Zivin and Lipper, 2008). Consequently, the adoption of land-management practices that can improve yields brings the same type of uncertainties that are associated with adopting new seed varieties or other innovative practices.

The limited empirical literature on the adoption of soil fertility management technologies is consistent with the general literature on smallholder technology adoption. In a study based on a survey of smallholder farmers in western Kenya, Marenya and Barrett (2007) report that resource constraints prevent farmers from adequately investing in soil fertility, even when their livelihoods depended crucially on agriculture. Moreover, many farmers in the study who tried using modern management techniques later dropped the practice. Dropout rates were particularly high for agro-forestry soil management techniques. A study by Odendo, Obare and Salasya (2009), which also uses data from Kenya, also found a negative relationship between resource constraints and investments in soils.

Problems that lead to land degradation in the first place often stand in the way of improved practices as well. Chief among these are tragedy-of-the-commons problems, where unfettered access results in the over-use of land resources through over-grazing or shifting agriculture. The related problem of weak property and tenure rights also discourage sustained investments in soil fertility. In both instances, farmers are not confident that they will be able to claim future productivity gains from current efforts. Potentially, both types of problems can be resolved in a project setting, but compensating for the absence of working formal or informal land institutions adds to the cost of the project and can introduce a high level of risk from coordination failures. [25]

It is also worth mentioning that carbon sequestration can be an ancillary benefit of activities focused on other objectives. This is especially true of group of actions designed to promote agricultural productivity in a sustainable way. For example, the development of farming approaches that conserve soil moisture or soil nutrients can generate costs savings for farmers and deliver sequestration as well. Developing new high-yielding seeds that promote intensification can lead also to positive "leakages" when, in the aggregate, they reduce the conversion of forests to farmland. Moreover, though a sharp distinction is made between mitigation and adaptation under the UNFCCC framework, the distinctions become especially blurred in the case of land-use. To continue the example above, the development of soil management technologies that conserve soil moisture and water resources also increase resilience to climate change. This implies an important role for government-supported agricultural research that has resource management and sustainability objectives in mind. A recent World Bank (2010) points to Brazil's efforts in low fertility Cerrados areas as an example of sponsored research that jointly promotes productivity, adaptation and mitigation.

Carbon sequestration and other environmental services

Though the link between soil carbon sequestration and soil fertility is emphasized, agriculture is associated with a wide range of externalities. As detailed by Lichtenberg (2002), agriculture is also a major contributor to environmental pollution through pesticides, fertilizers, animal wastes and sediment releases. While simultaneously affecting the environment, agriculture also depends on the environment. Agricultural productivity is enhanced by services provided by the natural environment, such as pollination, water supply, and pest control. Agriculture may reciprocate by contributing to the stability or productivity of the natural environment, such providing support for bird or insect populations.

Daily (1997), cited in Heal and Small (2002: 1347) lists the various ecosystem services, most if not all of which can be also be attributed to agriculture. Some are better measured than others and most of them are also interconnected.[26] These ecosystem services can be divided into four somehow different types (MEA 2005): i) provisioning services, mainly associated with production of food, fiber, fresh water, and hydropower; ii) regulating services, mainly associated with affecting environmental conditions that include flow regulation,

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[25] A counter-example is given in Minten et al. (2010), where good extension and well-defined property rights resulted in the adoption of new composting methods by smallholder farmers that improved productivity and soil fertility.
[26] The list includes: control of the vast majority of potential agricultural pests; cycling and movement of nutrients; detoxification and decomposition of wastes; dispersal of seeds; generation and preservation of soils and renewal of their fertility; maintenance of biodiversity; mitigation of droughts and floods; moderation of weather extremes and their impacts; pollination of crops and natural vegetation; protection from the sun's harmful ultraviolet rays; protection of coastal shores from erosion by waves; provision of aesthetic beauty and intellectual stimulation that lift the human spirit; purification of air and water; stabilization of the climate.

recharge groundwater basins, water quality regulation, climate regulation, air quality, and carbon sequestration; iii) cultural services, mainly associated with recreation and ecotourism, aesthetic values, spiritual renewal, religious and cultural values; and supporting services, mainly associated with soil formation and fertility, photosynthesis, nutrient cycling and water cycling.

In some instances, positive externalities associated with farming practices can be used to earn a premium for an associated product – for example, coffee grown in a way that encourages biodiversity. Even so, there can be large disparities between what consumers are willing to pay and the notional values of the associated environmental service or the cost of providing it. [27]. Efforts have been made to market carbon in a similar way and some third-party certifications focus on processes that safeguard the environmental integrity of the project credits. However, early evidence suggests that labels or certifications are of secondary importance for project credit pricing (Conte and Kotchen, 2009).

As Antel and Capalbo (2002) point out, many important phenomena in agriculture involve the behavior of complex systems whose behavior is affected by the interactions of two or more subsystems. In turn, because ecosystem services are interweaved, policies that address only one particular service or a subset of services may lead to distortive outcomes. Said in a different way, because agriculture is a complex and interactive system, creating an incentive mechanism that pays for only one stream of natural resource services may lead to perverse and unexpected outcomes when the payments affect other services adversely. In the particular context of carbon sequestration, the modification of management practices changes the overall economic profitability of their business as well as the level of externality impact on the natural system (Antle and Capalbo, 2001; Pfaff et al. 2000). In some instances, the positive aspects of improving soil carbon complement other environmental services such as the provision of water resources. However, this is not guaranteed.

A generalization of the idea of paying for greenhouse gas mitigation is the idea of paying farmers or communities directly for undertaking a range of activities that safeguard environmental resources. For example, payments for environmental services (PES) have been used for protecting municipal water supplies in Colombia, Mexico, Ecuador and El Salvador (Pagiola, Arcenas and Platais, 2004). And in the case of Costa Rica, PES programs have been used to encourage carbon sequestration while simultaneously protecting watersheds, biodiversity and scenic beauty (Wunder, Engel and Pagiola, 2008).[28] The approach is attractive since conservation outcomes are rewarded directly. Moreover, it also provides a mechanism for harnessing revenue from dispersed beneficiaries to pay for local activities that generate positive externalities, which is itself an underlying motive for the CDM.

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[27] See, for example, the discussion in Moon et al. (2002).

[28] See also a comparative analysis pf PES systems by Wunder, Engel and Pagiola (2008) and a review of PES efforts in Brazil's Amazonia by Hall (2008).

A case study of how carbon income incentives affect projects with multiple objectives is given by Nelson and de Jong (2003) and Löbrand, Rindefjäll and Nordqvist (2009); both papers discuss Scolel Té, a land-use agro-forestry sequestration project in Chiapas, Mexico established under a United States sponsored pilot project and part of the UNFCCC's Activities Implemented Jointly (AIJ) program.[29] The pilot featured a mix of community development and environmental objectives organized around a local trust fund (Fondo Bilclimatico), established in 1997 to broker carbon contracts between farmers and the voluntary carbon market. Under the AIJ, carbon credits were not eligible for credit against future greenhouse gas reduction commitments, but long-lived programs were eligible for conversion under the CDM once it was established. An effort was made in 2002 to assess the project's eligibility for conversion. Although the project currently remains outside of the CDM, Löbrand, Rindefjäll and Nordqvist (2009) argue that efforts to make the project viable under the CDM have resulted in a shift in emphasis away from the social and environmental objectives toward the provisioning of carbon sequestration.

As discussed, one of the hurdles with carbon sequestration projects has to do with the cost of coordinating actions among a large number of project participants. And one characteristic of PES systems is that they provide a shared mechanism for delivering payments for services. Shared organizational structures can be put to other uses as well. An example is Niger's Community Action plan, designed to organize local government to deliver services that promote development. In this case, the program promotes social protection, the build-up of local infrastructure, in addition to pilot soil conservation and afforestation projects (World Bank, 2010).

Paths forward

To summarize, there are substantive mitigation opportunities associated with agriculture, and the CDM has proven successful in funneling private capital into certain types of agricultural mitigation projects, primarily projects that convert organic waste products to energy and projects that limit methane emissions. However, large opportunities for mitigation remain related to land use that the CDM in its current form has not tapped. In this section, we look at how the CDM can be improved to partially redress current restraints. Even so, because the CDM is not intended to fund ancillary benefits separate from mitigation, it is likely that land-use projects will remain underfunded. We then discuss supplemental or alternative mechanisms, within or outside of the UNFCCC framework.[30]

Modifying the CDM

As discussed, uncertainties about the permanence of agricultural land-use sequestration have resulted in restrictions on how agricultural credits are created and how they are valued in the marketplace. In addition, project characteristics add to the cost of implementing land-use projects, even when underlying abatement

[29] The AIJ program was a voluntary predecessor of the CDM, established as an umbrella framework for national voluntary mitigation pilot projects. See Larson and Breustedt (2009).
[30] See a related discussion about institutional design and forestry projects by Forner et al. (2006).

costs are low. Still, there are several ways that the current implementation rules can be changed so that they might benefit from the substantial investment flows that the CDM has been able to harness for other sectors.

Perhaps the most promising area has to do with reducing the cost of evaluating and monitoring soil sequestration outcomes. To start, it is worth pointing out that all parties to the UNFCCC have, individually, already settled on or will soon settle on a methodology for calculating the amount of greenhouse gas sequestered by soils or released through changes in land use. This is because all parties to the Convention are expected to declare national greenhouse gas inventories. Moreover, Annex I countries are asked to submit annual inventory reports and have done so since 1996. [31] The reports have economic significance, since the factor in determining the extent to which countries have met their treaty obligations.

Lokupitiya and Paustian (2006) describe the reporting process and review the methods. They conclude that methodologies used currently to account for soil carbon inventories in developing countries are weak, but they attribute this primarily to weak measurement networks and the consequent lack of location-specific activity data, problems that can be remedied through fundamental investments. Ringius (2002) and González-Estrada et al. (2008) report on the benefits and hurdles associated with soil sequestration projects in the context of Sub-Saharan Africa; Soto-Pinto et al. (2010) describe field measurements for mixed land use in Chiapas, Mexico.

Finding reliable ways to calculate the impact of land-use practices on soil carbon sequestration that take into account local agro-climatic differences are also important for developing efficient policies. For example, in a study based on the United States, Antle et al. (2003) show that mitigation contracts based on per-ton sequestration incentives are five times more efficient than contracts that pay farmers to adopt soil conservation practices on a per hectare basis.

All of this points to a need for site-specific measures of how agricultural land-use practices affect net greenhouse gas emissions. It also indicates the possibility that methodologies currently employed in developed countries to assess their compliance with pledged emission reductions can be used to quantify the net benefits of agricultural land-use projects in developing countries. To be practical, this would in turn require adjustments in the types of baseline methodologies accepted by the CDM Board. Approaches put forth recently include a household multiple-criteria approach and related bench-marking techniques.[32] A related idea is to allow trading of offsets within sectors. This has appeal, since a land-use offset created under the CDM would be matched with a land-use emission from a regulated market using a common methodology.

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[31] The UNFCCC's inventory reporting requirements are described on its website, available on the Internet at: http://unfccc.int/national_reports/items/1408.php (downloaded on October 19, 2010.)

[32] See Gonzalez-Estrada et al. (2008). Anagnostopoulos, Flamos and Psarras (2004) discuss benchmarking applications for CDM and JI energy projects.

A second, somewhat technical point is that there is some scope under current CDM rules for addressing some of the investment hurdles associated with land-use projects. One recognized tool for establishing baselines uses what the CDM Board terms "barrier analysis" (UNEP Risoe, 2005). This step allows the project organizers to identify non-financial barriers that would prevent apparently economically viable investments from taking place outside of the CDM. This class of constraints can include risks associated with the technology, limits to credit, and barriers that result from prevailing practices. First-of-kind projects often benefit from barrier analysis as do projects that are traditionally difficult to finance. Still, barrier analysis tends to be used to address the special circumstances of an individual projects and may not be well suited to broad application as an integral part of frequently used methodologies.

Supplemental and additional mechanisms for investing in land-use mitigation projects

As discussed earlier, PES systems can be organized to reward multiple objectives, such as the preservation of biodiversity or the safeguarding of water supplies, and several examples of comprehensive systems are given in an earlier section. In this sense, land-use CDM project can be viewed as a kind of PES system that pays for carbon sequestration, a particular type of environmental service. However, the funding of CDM projects is organized differently, since the Kyoto Protocol creates incentives for private payments. In general, the same is not true for the ancillary services provided by land-use projects and their financing is left to governments, international organizations and voluntary organizations. These sources are likely constrained, so land-use projects will be under-funded even if the private sector adequately funds sequestration. Fortunately, there are old and new mechanisms that could be harnessed to better fund agricultural land-use projects.

The first has to do with innovations in carbon funds. While it is difficult to find examples of mechanisms that leverage carbon revenue streams to finance the full set of benefits from land-use projects, several funds pursue multiple objectives linked to conservation and the promotion of sustainable agriculture and development. Examples include the BioCarbon Fund, the Community Development Carbon Fund, both managed by the World Bank, and the World Wildlife Fund's conservation-carbon-finance projects.

In addition, multi-donor financing mechanisms have been established in recent years that can be used to supplement land-use mitigation activities. The largest and oldest is the Global Environmental Facility (GEF), a grant-making institution established in 1991 as a pilot project within the World Bank. The institution is now the financing instrument for the UNFCCC, as well as several other environmental conventions.[33] Though the GEF climate program is diffused across capacity building and adaptation programs, there is scope for mitigation activities and, in the case of agriculture, there is overlap with land management efforts designed to slow desertification that are also managed by the GEF.

[33] Included are the Convention on Biological Diversity, the Stockholm Convention on Persistent Organic Pollutants, and the UN Convention to Combat Desertification.

In 2008, two climate investment funds were established under UNFCCC auspices[34]. The Clean Technology Fund is designed to speed up the transfer and deployment of low-carbon technologies in order to slow greenhouse gas emissions. The programs are designed and implemented by countries with assistance from the Regional Development Banks and the World Bank Group. Fourteen country and regional plans were endorsed through 2010, funding US$4.4 billion in programs. Potentially, the fund could be tapped to address land-use mitigation efforts, although that has not yet occurred (World Bank, 2010).

The second fund, the Strategic Climate Fund, funds programs in three areas relevant for agriculture. The first is the Forest Investment Program (FIP), which is intended to support developing countries efforts to stem deforestation and forest degradation. The program is also meant to build-up experience in anticipation of REDD (reduced emissions from deforestation and degradation). The program funds efforts to encourage alternatives to extensive agricultural practices that can drive deforestation. A second pilot program for climate resilience (PPCR) is meant to integrate adaptation efforts into development planning and implementation. However, the program has relevance to out discussion, because some adaptation activities also lead to mitigation outcomes. For example, the Niger program discussed above is partially finance by the PPCR (World Bank, 2010). The third window, Scaling up Renewable Energy (SREP), promotes renewable energy projects, including biomass energy pilots in rural areas.

Another potential source of financing is more recent. In the area of mitigation, COPs in Copenhagen and Cancun have focused on voluntary steps that developing countries can take to slow emissions or improve sinks, and on new vehicles to finance those mitigation efforts[35]. As part of that process, developing countries have been asked to submit a list of policies, programs and projects designed to mitigate domestic emissions, which are known as Nationally Appropriate Mitigation Actions (NAMAs). By the close of 2010, 44 countries had signaled their intention to undertake domestic mitigation in some form.[36] In the context of NAMAs, agriculture is a natural area of focus for many of the countries because of the links between land-management, soil fertility and rural development. For example, in its NAMA, the Government of Ethiopia proposes projects that would add compost to agricultural lands and implement agro-forestry projects to improve rural livelihoods and sequester carbon in soils.

A related Green Climate Fund was introduced in Copenhagen and approved in Cancun that might provide direct funding to developing country governments for adaptation and mitigation efforts under NAMAs.

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[34] The funds operate as trust funds administered by the World Bank. CIF stakeholders include the Multilateral Development Banks, UN and UN agencies, Global Environment Facility (GEF), UN Framework Convention on Climate Change (UNFCCC), Adaptation Fund, Bilateral Development Agencies, Non-Governmental Organizations, Indigenous Peoples, Private Sector Entities, and Scientific and Technical Experts

[35] Each year, the UNFCCC holds a meeting of its members, known as a Conference of the Parties (COP).

[36]An updated list of NAMAs is available on the Internet at: www.unfccc.int/home/items/5265.php.

Another idea, introduced by the Government of New Zealand, would be to finance NAMAs using tradable credits similar to CERs (Macey, 2009).

Conclusions

Agricultural activities are an important and ubiquitous part of the ongoing build-up of atmospheric greenhouse gases, and they are also an abundant source of low-cost mitigation opportunities in developing countries. Currently, the Clean Development Mechanism is the only formal channel by which countries that have pledged to reduce greenhouse gas emissions can invest in credit-earning mitigation projects in developing countries. The CDM has proved successful at mobilizing capital for mitigation projects and is on-track to exceed initial expectations. Still, the sectoral and geographic distribution of projects has been narrow. Moreover, to the degree that model predictions of mitigation potential are a fair gauge, the CDM has not tapped deeply into the reserve of mitigation opportunities.

Within the agricultural sector, the CDM has been an effective conduit for mitigation projects that use residual agricultural organic matter as an alternative fuel source and projects that manage methane from composting and from manure. However, land-use projects that are designed to sequester carbon in soils face special hurdles under current rules. This is significant, since changing how land is used an inexpensive way to slow the buildup of atmospheric carbon stocks, and because managing soil carbon stocks is important for agricultural productivity, especially in Africa where soils are badly degraded.

At the same time, addressing land-use in a project context is difficult. The projects need to deal with the permanency of the mitigation they achieve in the short run and account for the cascading consequences of altering dynamic soil systems. Moreover, the degradation of lands often arises because of incomplete property rights and common use. As a consequence, reversing this type of degradation faces coordination hurdles, as effective management requires the participation of many stakeholders. What's more, local conditions factor significantly in soil systems, so that the set of parameters used to establish net emission outcomes vary from place to place, making it difficult to replicate successful projects. All of this adds to steeper monitoring, measurement and implementation costs, making agricultural land-use projects less attractive to investors. Consequently, agricultural land-use projects, and especially soil carbon sequestration projects, are scarce, even in markets outside of the Kyoto Protocol where they face fewer restrictions.

Even so, the consequences of land-use changes are measured as part of the inventory-taking that parties to the UNFCCC are obligated to report. In addition, land-use changes affect carbon markets because they are part of the accounting that determines the demand of developed countries for CDM offsets. Because of this, considerable effort has been put into measurement methodologies and these methods could be adapted for agricultural projects under the CDM. To the extent that parties to the UNFCCC are confident in the accuracy of the methodologies and to the extent that soil information networks are built-up, this opens the door for including agricultural land-use projects under the CDM.

Still, doing so may still leave investments in soils underfunded. This is because there are largely positive externalities associated with land use projects. Well thought-out and appropriately funded projects can generate ancillary benefits by protecting habitats, watersheds and by contributing to food security and poverty reduction. Paying for the carbon component alone seldom provides the resources to generate all ancillary benefits. This leaves a role for communities and governments interested in sustainable agricultural development, biodiversity and other aspects of natural resource stewardship to fund the remaining investment gap.

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Table 1: Estimated potential for GHG mitigation in 2030 by sector at or below $20/tCO_2e.

	Total	Developing Countries
Agriculture	1.60	1.10
Forestry	1.25	1.05
Energy	1.90	0.80
Buildings	5.50	2.85
Transport	1.75	0.13
Other	1.50	0.97
Total	13.50	6.90

Note: potential given in Gt CO_2e per year. Mitigation from burning agricultural residue is attributed to sector in which the fuel-use takes place. The IPCC estimates that mitigation opportunities for this class of project at 1.26 Gt CO_2e per year. Source: Barker et al. (2007), Smith et al. (2007)

Table 2: CDM projects by type and expected mitigation impact by 2012 and 2020

	Projects		Mitigation impact by 2012		Mitigation impact by 2020		Average project impact ($ktCO_2e$)	
Project type	**number**	**share**	**$ktCO_2e$**	**share**	**$ktCO_2e$**	**share**	**2012**	**2020**
Agriculture	964	0.17	219,507	0.08	582,081	0.07	228	604
Land-use-forestry	58	0.01	16,638	0.01	69,109	0.01	287	1,192
Non-agriculture								
Hydro	1,558	0.27	482,160	0.17	1,894,491	0.22	309	1,216
Alternative energy	1,221	0.21	326,170	0.11	1,154,888	0.13	267	946
Energy Efficiency	837	0.14	332,619	0.12	1,139,571	0.13	397	1,361
Methane avoidance	340	0.06	191,296	0.07	596,638	0.07	563	1,755
Landfill gas	326	0.06	204,097	0.07	537,122	0.06	626	1,648
Assorted gases	145	0.02	340,797	0.12	904,581	0.10	2,350	6,238
Biomass energy	141	0.02	36,958	0.01	101,004	0.01	262	716
Fossil fuel switch	133	0.02	191,523	0.07	585,274	0.07	1,440	4,401
Cement	44	0.01	35,444	0.01	76,590	0.01	806	1,741
Transport	34	0.01	10,157	0.00	39,160	0.00	299	1,152
HFCs	23	0.00	476,541	0.17	1,100,353	0.13	20,719	47,841
Total	5,824	1.00	2,863,906	1.00	8,780,862	1.00	492	1,508

Note: The non-agriculture categories are based on Risoe's classification system, net of those projects considered agricultural by the authors.

Table 3: Host countries ranked by the number of CDM projects hosted

	All projects			Agricultural projects			Land-use-forestry projects		
Rank	Host	Number	Cumulative share	Host	Number	Cumulative share	Host	Number	Cumulative share
1	China	2,316	0.398	India	326	0.338	India	9	0.155
2	India	1,549	0.664	Brazil	137	0.480	Kenya	8	0.293
3	Brazil	365	0.726	China	119	0.604	Uganda	6	0.397
4	Mexico	176	0.757	Mexico	104	0.712	Colombia	6	0.500
5	Malaysia	136	0.780	Malaysia	77	0.791	China	4	0.569
6	Vietnam	129	0.802	Philippines	53	0.846	Chile	3	0.621
7	Thailand	126	0.824	Indonesia	33	0.881	Congo DR	2	0.655
8	Indonesia	114	0.843	Thailand	27	0.909	Bolivia	2	0.690
9	South Korea	85	0.858	Chile	8	0.917	Moldova	2	0.724
10	Chile	77	0.871	Honduras	7	0.924	Brazil	2	0.759
11	Philippines	76	0.884	Sri Lanka	5	0.929	Ethiopia	1	0.776
12	Colombia	68	0.896	Ecuador	5	0.935	Ghana	1	0.793
13	Peru	40	0.903	Israel	5	0.940	Madagascar	1	0.810
14	South Africa	39	0.909	Colombia	5	0.945	Albania	1	0.828
15	Argentina	38	0.916	Nepal	4	0.949	Lao PDR	1	0.845
16	Israel	33	0.922	Cyprus	4	0.953	Paraguay	1	0.862
17	Honduras	31	0.927	Vietnam	4	0.957	Tanzania	1	0.879
18	Pakistan	25	0.931	Uruguay	3	0.961	Nicaragua	1	0.897
19	Ecuador	23	0.935	Morocco	3	0.964	Costa Rica	1	0.914
20	Sri Lanka	21	0.939	Kenya	3	0.967	Uruguay	1	0.931

Source: Risoe (2010) and authors' calculations. Note: The full list of host countries is given in Annex table 1.

Table 4: Methodologies used for agriculture and land-use-forestry projects

Methodology	Number of projects	Mitigation ($ktCO_2e$) 2012	2020	Project scale	Mitigation action
AMS-I.D.	252	37,615	95,220	Small scale	Displacement of electricity produced by more GHG-intensive means
ACM6	191	71,139	206,925	Large scale	Renewable energy
AMS-III.D.	191	15,661	42,668	Small scale	GHG destruction
AMS-I.C.	187	27,259	77,867	Small scale	Displacement of more GHG-intensive thermal energy or heat
AMS-III.F.	48	4,757	14,635	Small scale	GHG destruction
ACM2	42	18,850	53,332	Large scale	Renewable energy
AMS-III.E.	28	12,790	32,279	Small scale	GHG emission avoidance
ACM3	26	11,120	28,032	Large scale	Fuel Switch and renewable energy
AR-AMS1	23	773	6,213	Small scale	GHG removal by sinks
AMS-III.R.	18	2,226	9,314	Small scale	GHG destruction and fuel switching
AMS-III.H.	15	1,464	5,630	Small scale	GHG destruction
AM36	12	5,295	19,332	Large scale	Renewable energy
AM39	11	7,666	17,707	Large scale	GHG emission avoidance
ACM10	9	3,629	13,862	Large scale	GHG destruction
ACM18	8	2,450	13,381	Large scale	Renewable energy
AM25	7	1,389	4,994	Large scale	GHG emission avoidance, renewable energy
AMS-I.A.	7	650	1,885	Small scale	Displacement of more GHG-intensive service
AMS-I.E.	7	865	3,260	Small scale	Displacement of non-renewable biomass by renewable sources
AR-AM4	7	3,701	12,985	Large scale	GHG removal by sinks
AR-AM5	7	6,436	28,183	Large scale	GHG removal by sinks
AR-ACM2	4	1,154	3,183	Large scale	GHG removal by sinks
AR-AM3	4	632	1,591	Large scale	GHG removal by sinks
AM73	3	870	3,323	Large scale	GHG destruction
AMS-III.G.	3	684	1,801	Small scale	GHG destruction
AMS-II.D.	2	47	183	Small scale	Energy efficiency
AR-AM2	2	1,077	3,314	Large scale	GHG removal by sinks
AM57	1	325	976	Large scale	GHG emission avoidance
AMS-II.F.	1	18	100	Small scale	Energy efficiency in agriculture
AMS-III.Q.	1	46	168	Small scale	Energy efficiency
AMS-III.Z.	1	134	413	Small scale	Energy efficiency, renewable energy, fuel switch
AR-AM10	1		3,444	Large scale	GHG removal by sinks.
AR-AM9	1	236	657	Large scale	GHG removal by sinks
AR-AMS3	1	24	55	Small scale	GHG removal by sinks

Note: Because some projects employ more than one methodology, the number of methodology appearances exceeds the number of analyzed projects. Source: Risoe (2010) and authors' calculations.

Table 5: Number of projects using selected methodologies by project-start year.

Methodology	2004	2005	2006	2007	2008	2009	2010	total
ACM10	5	40	7	5	1	0	2	60
ACM2	0	6	8	4	14	7	3	42
ACM3	0	7	1	5	5	2	6	26
ACM6	3	35	51	22	54	34	21	220
AM36	0	1	0	1	3	5	2	12
AM39	0	0	0	8	1	2	0	11
AMS-I.C.	0	12	18	24	50	32	51	187
AMS-I.D.	2	47	63	51	31	29	29	252
AMS-III.D.	0	14	84	29	28	24	12	191
AMS-III.E.	0	2	12	4	4	2	4	28
AMS-III.F.	0	0	5	17	14	7	5	48
AMS-III.H.	0	0	0	0	5	2	8	15
AMS-III.R.	0	0	0	1	2	1	14	18
AR-AMS1	0	0	0	2	10	9	2	23
Other	0	2	5	9	20	7	26	69

Note: Because some projects employ more than one methodology, the number of methodology appearances exceeds the number of analyzed projects. Source: Risoe (2010) and authors' calculations.

Table 6: CDM projects expected mitigation impact by core set of activities

	Number of projects	**Expected mitigation ($ktCO_2e$)**	
		2012	**2020**
Agricultural residues	615	153,768	428,634
Manure	288	52,837	119,486
Composting	60	12,883	33,861
Land use	57	16,614	69,054
Irrigation	1	18	100
Mangroves	1	24	55
Total	1,022	236,145	651,189

Source: Risoe (2010) and authors' calculations

Table 7: Volume and value of project-based transactions, 2008-2009

	2008		2009	
	Volume $MtCO_2e$	Value US$ Million	Volume $MtCO_2e$	Value US$ Million
CDM	404	6,511	211	2,678
Joint implementation	25	367	26	354
Voluntary market	57	419	46	338
Total	486	7,297	283	3,370

Source: State and Trends of the Carbon Market 2010, World Bank.

Table 8: Land-use based offsets traded on voluntary OTC markets.

	Volume ($ktCO_2e$)		Share of voluntary market (%)	
Project type	**2008**	**2009**	**2008**	**2009**
Afforestation/Reforestation	4,091	4,253	8.00	10.00
Avoided Deforestation	730	2,846	1.00	7.00
Forest Management	431	1,349	1.00	3.00
Agricultural Soil	267	1,250	0.50	3.00
Agro-Forestry		625		1.00
Other Land-based projects	130	109	0.03	0.03
Total	**5,649**	**10,432**	**10.53**	**24.03**

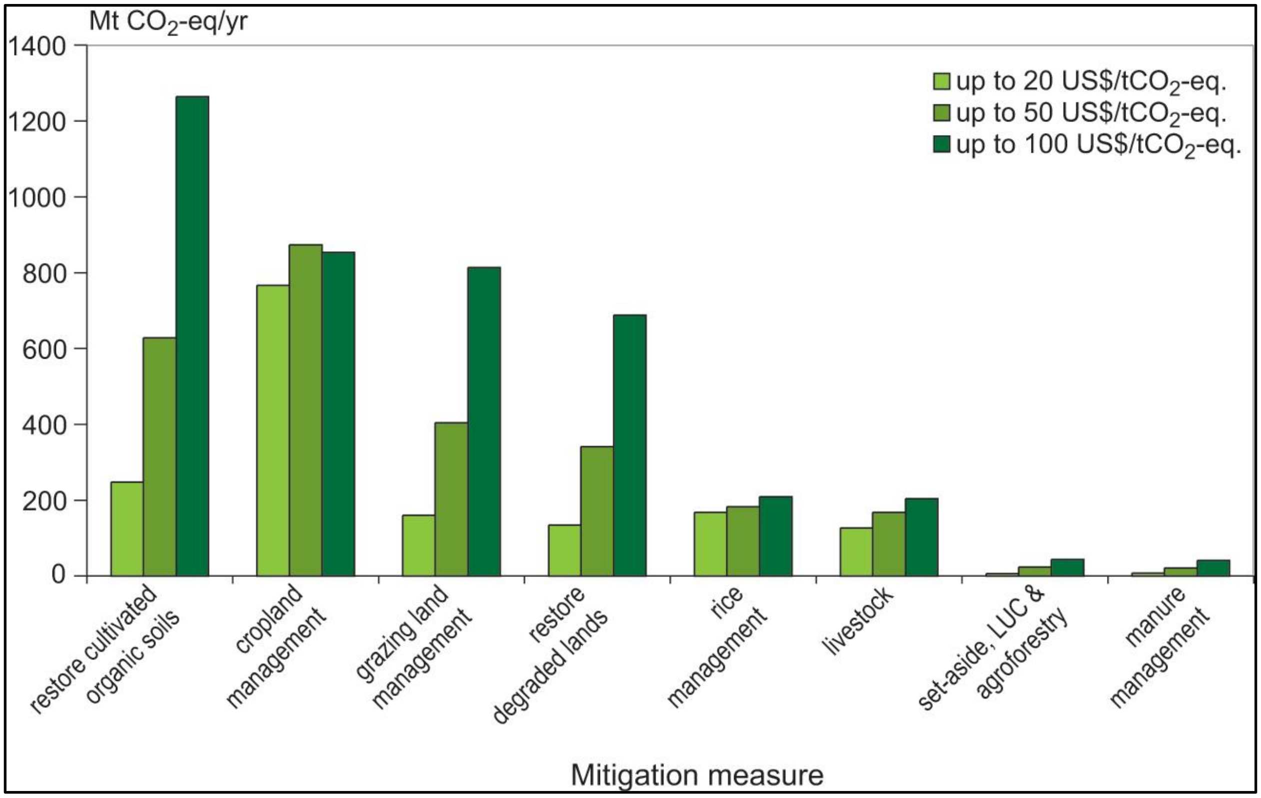
Source: Hamilton et al. (2010).

Table 9: Carbon soil sequestration and net revenue gain under alternative farming practices.

	No external inputs	Improved seeds	Improved seeds and fertilizer	Agroforestry
Carbon sequestration rate (tCO_2e)	0.5	1.0	1.5	4.0
Values ($/ha)				
Annual carbon payments	$1.15	$4.90	$8.65	$27.40
Annual revenues from yield improvements	$34	$225	$450	$225
Total additional revenues	$35	$230	$459	$252
Seed costs	$0	$29	$29	$23
Fertilizer costs	$0	$0	$60	$0
Additional labor costs	$45	$68	$90	$75
Total additional costs	$45	$68	$150	$75
Net revenues	-$10	$162	$309	$177

Note: Carbon is prices at $4.90 per ton CO_2e, maize at $0.15/kg. Source: Tennigkeit et al. (2009).

Figure 1: Potential for mitigation in agriculture at selected prices



Note: The totals exclude bioenergy and improved energy efficiency. Source: Smith et al. (2007)

Annex table 1: Number of CDM projects hosted by country and share of total

	Number of projects			Share of global total		
Host country	All Sectors	Agriculture	Forest	All Sectors	Agriculture	Forest
China	2,316	119	4	0.398	0.123	0.069
India	1,549	326	9	0.266	0.338	0.155
Brazil	365	137	2	0.063	0.142	0.034
Mexico	176	104	0	0.030	0.108	0.000
Malaysia	136	77	0	0.023	0.080	0.000
Vietnam	129	4	1	0.022	0.004	0.017
Thailand	126	27	0	0.022	0.028	0.000
Indonesia	114	33	1	0.020	0.034	0.017
South Korea	85	0	0	0.015	0.000	0.000
Chile	77	8	3	0.013	0.008	0.052
Philippines	76	53	0	0.013	0.055	0.000
Colombia	68	5	6	0.012	0.005	0.103
Peru	40	2	1	0.007	0.002	0.017
South Africa	39	2	0	0.007	0.002	0.000
Argentina	38	3	1	0.007	0.003	0.017
Israel	33	5	0	0.006	0.005	0.000
Honduras	31	7	0	0.005	0.007	0.000
Pakistan	25	3	0	0.004	0.003	0.000
Ecuador	23	5	0	0.004	0.005	0.000
Sri Lanka	21	5	0	0.004	0.005	0.000
Guatemala	19	1	0	0.003	0.001	0.000
Panama	19	1	0	0.003	0.001	0.000
Kenya	18	3	8	0.003	0.003	0.138
Egypt	16	0	0	0.003	0.000	0.000
Morocco	16	3	0	0.003	0.003	0.000
Uzbekistan	15	0	0	0.003	0.000	0.000
Uganda	13	1	6	0.002	0.001	0.103
Uruguay	13	3	1	0.002	0.003	0.017
Armenia	12	1	0	0.002	0.001	0.000
Nigeria	10	0	0	0.002	0.000	0.000
Costa Rica	10	2	1	0.002	0.002	0.017
Dominican Republic	10	2	0	0.002	0.002	0.000
Cyprus	10	4	0	0.002	0.004	0.000
Moldova	9	0	2	0.002	0.000	0.034
Iran	9	0	0	0.002	0.000	0.000
United Arab Emirates	9	1	0	0.002	0.001	0.000
Nicaragua	8	1	1	0.001	0.001	0.017
Georgia	7	0	0	0.001	0.000	0.000
Cambodia	7	2	0	0.001	0.002	0.000
Tanzania	6	0	1	0.001	0.000	0.017
Azerbaijan	6	0	0	0.001	0.000	0.000
Papua New Guinea	6	0	0	0.001	0.000	0.000
Bolivia	6	1	2	0.001	0.001	0.034
El Salvador	6	2	0	0.001	0.002	0.000
Nepal	6	4	0	0.001	0.004	0.000
Congo DR	5	0	2	0.001	0.000	0.034
Jordan	5	0	0	0.001	0.000	0.000
Singapore	5	2	0	0.001	0.002	0.000

Source: Risoe (2010) and authors' calculations.

Annex table 1: Number of CDM projects hosted by country and share of total (continued)

	Number of projects			Share of global total		
Host country	All Sectors	Agriculture	Forest	All Sectors	Agriculture	Forest
Paraguay	4	0	1	0.001	0.000	0.017
Bangladesh	4	0	0	0.001	0.000	0.000
Cameroon	4	0	0	0.001	0.000	0.000
Mongolia	4	0	0	0.001	0.000	0.000
Rwanda	4	0	0	0.001	0.000	0.000
Syria	4	0	0	0.001	0.000	0.000
Tunisia	4	0	0	0.001	0.000	0.000
Lao PDR	4	1	1	0.001	0.001	0.017
Albania	3	0	1	0.001	0.000	0.017
Bhutan	3	0	0	0.001	0.000	0.000
Cuba	3	0	0	0.001	0.000	0.000
Côte d'Ivoire	3	0	0	0.001	0.000	0.000
Macedonia	3	0	0	0.001	0.000	0.000
Senegal	3	2	0	0.001	0.002	0.000
Madagascar	2	0	1	0.000	0.000	0.017
Fiji	2	0	0	0.000	0.000	0.000
Mauritius	2	0	0	0.000	0.000	0.000
Qatar	2	0	0	0.000	0.000	0.000
Sudan	2	0	0	0.000	0.000	0.000
Ethiopia	1	0	1	0.000	0.000	0.017
Ghana	1	0	1	0.000	0.000	0.017
Bahamas	1	0	0	0.000	0.000	0.000
Cape Verde	1	0	0	0.000	0.000	0.000
Jamaica	1	0	0	0.000	0.000	0.000
Lebanon	1	0	0	0.000	0.000	0.000
Lesotho	1	0	0	0.000	0.000	0.000
Liberia	1	0	0	0.000	0.000	0.000
Mali	1	0	0	0.000	0.000	0.000
Malta	1	0	0	0.000	0.000	0.000
Saudi Arabia	1	0	0	0.000	0.000	0.000
Serbia	1	0	0	0.000	0.000	0.000
Yemen	1	0	0	0.000	0.000	0.000
Zambia	1	0	0	0.000	0.000	0.000
Guyana	1	1	0	0.000	0.001	0.000

Source: Risoe (2010) and authors' calculations.